Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Facilitating the Deployment of Text-to-911 and Other Next Generation 911 Applications, and	)	PS Docket No. 11-153
	)	
Framework for Next Generation 911 Deployment	)	PS Docket No. 10-255

COMMENTS OF THE UNIVERSITY OF COLORADO, INTERDISCIPLINARY TELECOMMUNICATIONS PROGRAM

The University of Colorado's (CU) Interdisciplinary Telecommunications Program (ITP) respectfully submits the following comments to the Federal Communications Commission (FCC) for its consideration with respect to the Notice of Proposed Rulemaking in the Next Generation 911 Proceeding (NG911 NPRM), as published in the Federal Register on October 12, 2011, in the matter of "*Facilitating the Deployment of Text-to-911 and Other Next Generation 911 Applications*," Public Safety (PS) Docket No. 11-153 and "*The Framework for Next Generation 911 Deployment*," PS Docket No. 10-255[1]

I. BACKGROUND

The Interdisciplinary Telecommunications Program (ITP) is a graduate program in the University of Colorado's College of Engineering and Applied Science, located in Boulder, Colorado. Established in 1971, the Program has graduated over 3000 students from more than 50 countries. The curriculum focuses on the three disciplines important to telecommunications policy: the technology, economics, and legal/regulatory structure of modern communication networks. Students are trained to consider all three disciplines and to apply the information collected to questions of importance to the current telecommunications industry and regulators. These dockets were an opportunity for CU and ITP to involve students with researching several of the technical concerns surrounding texting-to-911 and other Next Generation 911 (NG 911) applications. A team of graduate students, guided by several professors (CU Team), conducted a series of lab studies on a GSM network to assess the various technical concerns in this matter and to provide specific measures around the

[1] FCC, Notice of Proposed Rulemaking in the Next Generation 911 Proceeding, [hereinafter NG911 NPRM], in the matter of PS Docket No. 11-153, *Facilitating the Deployment of Text-to-911 and Other Next Generation 911 Applications*, and PS Docket No. 10-255 and *The Framework for Next Generation 911 Deployment*, (adopted Sept. 22, 2011) *available at* http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db1012/DA-11-1703A1.pdf (published in the Federal Register on Oct. 12, 2011, (Vol. 76, No. 197).

concerns to texting to 911. They did so as an academic exercise and not to support any industry or commercial application.[2]

II. GENERAL STATEMENT of ISSUES and FINDINGS

This section summarizes the findings of the CU Team. For more detail, the reader is referred to Section III. At the outset of its research, the CU Team completed an extensive literature review, cataloging the current knowledge on the subject of texting to emergency communications as it appears in published research documents both domestically and internationally. This research confirmed that the primary technical reason that U.S. residents cannot text to 911 is because the current 911 system still uses legacy analog circuit-switched technology. [3] However, even when the current technology is replaced with digital Next Generation IP-based packet-switched technology (NextGen 911), several additional technical concerns linger. [4] These include: the reliability of such communications, delays in delivery, dropped or lost messages, and continuity with the call takers – ensuring that a string of text messages on an emergency call reach the same PSAP and 911 call taker. There were also indications that text messages get through the network when voice calls cannot and assist the network in handling the extreme call loads that occur during and immediately after major emergencies and natural disasters. The CU Team noted that discussions surrounding these technical concerns provided little or no lab testing or other measurement to assess the validity of the concerns or to measure their actual degree of impact. To fill this gap, the CU Team sought to quantify the following:

1. *Reliability*: A concern exists in the emergency communications industry that text messages to 911 are less reliable than mobile phone voice calls. However, the CU Team found that the reliability of text messages and mobile phone voice calls, in terms of data loss, are very similar. The CU Team's study tracked several hundred messages and found that all of the text messages sent were received by the cellular network, resulting in a "data loss rate" of 0% and a reliability level of 100%. Other researchers[5]

[2] However, in full disclosure, some of the time and efforts of the CU Team were partially funded by a gift to the CU Foundation from the Intrado Corporation, but the gift was not a contract or request to research specific options or interests. The results of the CU Team's work are presented here to be of assistance to the FCC.

[3] In 1968, the first call in the US using "911" to reach emergency help was made in Haleyville, Alabama, from the City Hall to the Haleyville Police Station (*Dispatch Magazine On-line*, "History of 911, Haleyvile - where 911 began," http://www.911dispatch.com/911/history/). Over the next twenty years the AT&T/Bell System built/expanded the system throughout the U.S., making "911" the (ubiquitous) standard number to reach help. It is important to note, however, that there are still remote locations where even the traditional 911 system is not yet implemented because of the cost to do so (*Dispatch Magazine On-line*, "Facts and figures, 2009." http://www.911dispatch.com/info/fact_figures.html).

[4] 4G Americas, "Texting to 9-1-1: Examining the Design and Limitations of SMS." 4G Americas, Oct-2010.

[5] Chwan-Lu Tseng, Joe-Air Jiang, Ren-Guey Lee, Fu-Ming Lu, Cheng-Shiou Ouyang, Yih-Shaing Chen, Chih-Hsiang Chang, "Feasibility study on application of GSM–SMS technology to field data acquisition", *Computers and Electronics in Agriculture*, Volume 53, Issue 1, August 2006, Pages 45-59, ISSN 0168-1699, 10.1016/j.compag.2006.03.005. http://www.sciencedirect.com/science/article/pii/S0168169906000494

have tested the reliability of Short Message Service (SMS) texts and found that the "data loss rate" over several thousand messages was less than 1%, resulting in a reliability level of 99 %. The statistical implication is that large samples might experience a small percentage of data loss, but overall the reliability for text messages is similar to that of voice calls.

2. *Time to Dial 911(Make a Mobile Phone Call) versus Time to Compose and Send a Text Message*. A concern also exists that it may take longer to compose and send a text message than simply to dial 911. However, the CU Team found that a text message of 60 characters can be sent in approximately the same time as it takes to set up a mobile voice call, in most cases 4 seconds. When signals are weaker, performance is similar and the time for most users is within 5 seconds, although occasionally (less than 10% of the time) the messages took more than 8 seconds.

   The CU Team found that the time required to compose a text message was negligible for at least two reasons: a) persons become adept at texting and can complete a text very quickly, and b) there are an increasing number of smartphone applications and other SMS short cuts that provide for pre-stored and automatically composed messages, such as contact information for an epileptic having a seizure, or to include location (global positioning satellite/GPS) coordinates.

   It is also worth noting that in situations where texting may be the only option, the specific delay is less relevant[6].

3. *Impact of Caller Movement*. A question that exists in the literature concerning signal strength is, "Does it matter if the caller is stationary or moving?" The CU Team's tests confirmed that the signal strength of a mobile phone voice call varies significantly when the caller is moving, rather than standing still. However, most messages were sent in the same amount of time as in the stationary case.

4. *Weak Signal Environments.* A question that has been raised by communications researchers is, "Are there any circumstances when a voice call cannot "connect" or "go through," but a text message can?" On the edge of a mobile phone signal coverage (where a phone might display "no bars"), or when the mobile phone signal is heavily obstructed, such as when the caller is in the mountains, in the midst of high rise buildings, inside a building, under a collapsed building following an earthquake or explosion, or in a trunk of a car, closet, container, etc., the signal is weak. The CU Team found that, in the case of fixed stationary antennas, there exist a signal threshold above which both a voice call or text message can communicate and below which neither can communicate. However, for a handheld mobile phone, the signal will vary with even small movements. In this situation, the CU Team observed cases when a weak signal existed and text messages got through while voice calls did not. Communication at the edge of coverage can be sporadic, allowing only momentary windows of communications coverage that are not long enough to support a voice call but a short burst of a text message can get through. In addition, some implementations of SMS automatically keep trying to send a text message until a transmission window opens.

[6] J. Medland, "UK - Emergency SMS Trial." British Telecommunications plc, n.d., p. 2.

5. *Impact of Message Length*: Another current question in the emergency communications industry is, "Does the length of a text message affect its delivery time?" The CU Team found that the size of a text message does not significantly impact the time required to transport a text message to the SMS center. As the message size increased from: a) 1 character to 60 characters, and b) from 60 characters to 160 characters, the time to transmit the message increased by only 20% at each jump. Additionally, the difference in time required to transmit the smallest message (1 character) and the largest message (160 characters) was less than a factor of two.

6. *Confirmation of Text Message Delivery:* Since people know that they have reached 911 via a mobile voice call when the call-taker answers, 911 researchers have asked, "How do people know whether their texts arrive?" The sender simply receives a "Sent" notification from the SMS center, but that does not guarantee that the text has been delivered to the dialed party, in this case 911. However, many international systems address this concern by the initial call taker responding with a text message back to the sender.

7. *Dropped Calls*: Voice calls require a connection that is typically much longer than the few seconds required to send a text message. Does this make them more susceptible to being dropped? The CU Team's tests showed that, once connected, most voice calls (90%) did not drop when the signal become weaker. This was true even when the signal became weaker than the minimum signal level required to initially set up the call. Instead, calls connections could be maintained for minutes at a time at this lower signal level. However, when the signal was weak, the quality of the reception became impaired with voice quality below acceptable levels for conversation. Many mobile phone users have experienced this when they are on a call but can hear only portions of words or broken transmissions.

8. *Continuity and Consistent Contact with 911 Call Takers.* Most persons appreciate the benefit of staying connected with the same 911 call taker through a crisis – or being able to be reconnected with that person if dropped. A gap in the conversation with a call taker may lose valuable information for the call taker or feedback to the caller. Since text messages replace the voice conversation with a string of texts, there is concern that callers may not have their texts routed to the same PSAP or 911 call taker. However, the CU Team found that technology has been developed that can route a string of text message to the same PSAP and/or 911 call taker.

9. *Congested Public Telephone Networks:* What is the comparative ability to get mobile voice calls versus text messages to 911 when the available infrastructure is heavily congested with an exceptional number of calls, such as during and after a major accident, public event, explosion, or natural disaster (earthquake, fire, flood, tsunami, etc.)? An emergency reported via text to 911 will consist of a session of several texts being passed between the caller and call taker. The CU Team found that with GSM technology, the wireless interface can carry 18 times as many text-to-911 sessions as voice-to-911 calls.

10. *Congested Call Loads at PSAP* - What is the comparative ability of 911 call-takers to handle voice calls versus text messages in a high-volume emergency situations or disaster? The CU Team found that text to 911 has several advantages in these

scenarios. Automatic filters in each PSAP could queue and prioritize messages so that callers never receive a "busy" signal or recording, and similar calls could be quickly correlated for the call takers. Call takers can also manage multiple text to 911 caller exchanges at the same time. Also, it is easier to forward ongoing text to 911 sessions to other less-loaded PSAPs. These features could be tremendously important in all future situations where 911 call-takers must manage crushing call loads during large-scale emergencies and natural disasters.

III. DETAILED FINDINGS

The CU Team drew on two lines of research, a literature review and laboratory testing. The first was a literature review of text to 911[7] communications in the U.S. and other countries. The material gathered was limited to publicly available documents in English. No attempts were made to contact or interview U.S. or international agencies. Generally, the primary reason, and often sole reason for most international text to 911 implementations is to serve hearing and speech impaired persons as well as more general initiatives for persons with disabilities.[8] Countries with text to 911 initiatives include Australia,[9] [10] Canada,[11] Denmark,[12] Estonia,[13] Finland,[14] France,[15] Hong Kong,[16] Iceland,[17] Luxembourg,[18] [19] the Netherlands,[20]

[7] The three digit dialing code varies from country to country. For instance it is 112 in European countries and 000 in Australia. Similarly, not all countries refer to public safety answering point as PSAPs. Nevertheless, for consistency we will refer to 911 and PSAPs in this document.

[8] A number of European Union emergency text initiatives appear to be driven by legislation requiring equal access to emergency services for the disabled. Directive 2009/136/EC of the European Parliament and of the Council of 25 November 2009 amending Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services, Directive 2002/58/EC concerning the processing of personal data and the protection of privacy in the electronic communications sector and Regulation (EC) No 2006/2004 on cooperation between national authorities responsible for the enforcement of consumer protection laws, Official Journal of the European Union, Vol. L 337 (2009), pp. 0011-0036.

[9] S. Conroy, "Address to CommsDay Summit 2010," Sydney, Australia, 20-Apr-2010.

[10] "SMSAssist | Western Australia Police." [Online]. Available: http://www.police.wa.gov.au/Yoursafety/SMSAssist/tabid/982/Default.aspx. [Accessed: 07-Dec-2011].

[11] Canadian Radio-television and Telecommunications Commission, Interconnection Steering Committee (CISC), "Text Messaging to 9-1-1 (T9-1-1) Service," ESRE0051, Jan. 2010.

[12] "112 - The emergency number in Denmark." [Online]. Available: http://ec.europa.eu/information_society/activities/112/ms/dk/index_en.htm. [Accessed: 07-Dec-2011].

[13] A. Jakel, "Estonian ERC SMS112 project." Estonian Emergency Response Centre, n.d. p. 5.

[14] Working Group For Emergency Communications, "Implementation of an SMS-Based Emergency Service in Finland," FICORA, Helsinki, Finland, Jul. 2005. p. 3.

[15] "A new emergency number in France□: 114." [Online]. Available: http://www.ives.fr/index.php/news/266-a-new-emergency-number-in-france-114. [Accessed: 07-Dec-2011].

[16] Hong Kong Police Force, "992 Emergency SMS User Guide." Hong Kong Police Force, n.d. p. 1.

Norway,[21] Portugal,[22] Spain,[23] Sweden,[24 25] the U.K.[26 27 28] In most countries the service requires pre-registration. In many countries anyone can register although the registration process is only advertised to the hearing impaired community.

The CU Team's laboratory experiments were conducted at the University of Colorado. The basic concept was to set up voice calls and send text messages using a Telit computer-controlled GSM-based communication board (Telit Board) rather than a mobile phone. The Telit Board allowed the team to make repeatable tests and provided a solid connection between the boards antenna input and the lab equipment for more trustworthy results. With this lab set up the Telit Board's use of the wireless interface, as it communicated with a base station located near the campus, was observed. From these observations, the channel use was timed. This equipment set-up is shown in Figure 1 with the equipment listed in Table 1.

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[17] The National Center on Emergency Communication in Health (Norway), "SMS in Emergency Communication," National Center on Emergency Communication in Health (Norway), Bergen, Norway, 978-82-8210-017-5, Nov. 2009. p. 3, 9.

[18] Rescue Service Agency Luxembourg, "112 SMS service in Luxembourg." n.d. p. 2.

[19] C. Bruck, "112-SMS in Luxembourg." Administration des services de secours, n.d. p. 9.

[20] "112 - The emergency number in the Netherlands." [Online]. Available: http://ec.europa.eu/information_society/activities/112/ms/nl/index_en.htm. [Accessed: 07-Dec-2011].

[21] Public Enterprise Vilnius Rehabilitation Centre of the Deaf, "Deaf Access 112 Adaptation of Services of Emergency Call Number 112 to the Deaf Feasability Study." Public Enterprise Vilnius Rehabilitation Centre of the Deaf, Aug-2010. p. 34.

[22] "112 - The emergency number in Portugal." [Online]. Available: http://ec.europa.eu/information_society/activities/112/ms/pt/index_en.htm. [Accessed: 08-Dec-2011].

[23] "Europa - Information Society." [Online]. Available: http://ec.europa.eu/information_society/activities/112/ms/es/index_en.htm. [Accessed: 08-Dec-2011].

[24] P. Palm, "112 SMS Service." SOS Alarm (The Swedish Government and Swedish Association of Local Authorities and Regions), 20-Apr-2011. p. 2, 3.

[25] SOS Alarm (The Swedish Government and Swedish Association of Local Authorities and Regions), "SMS 112 in Sweden." SOS Alarm (The Swedish Government and Swedish Association of Local Authorities and Regions), n.d. p. 4.

[26] *See* Medland, *supra* note 6. p. 2.

[27] "Ofcom | UK consumers benefit from European telecoms law changes." [Online]. Available: http://consumers.ofcom.org.uk/2011/05/uk-consumers-benefit-from-european-telecoms-law-changes/. [Accessed: 06-Dec-2011].

[28] emergencySMS trial, "SMS to the emergency services | EmergencySMS," *emergencySMS*, 2009. [Online]. Available: http://www.emergencysms.org.uk/. [Accessed: 23-Aug-2011].

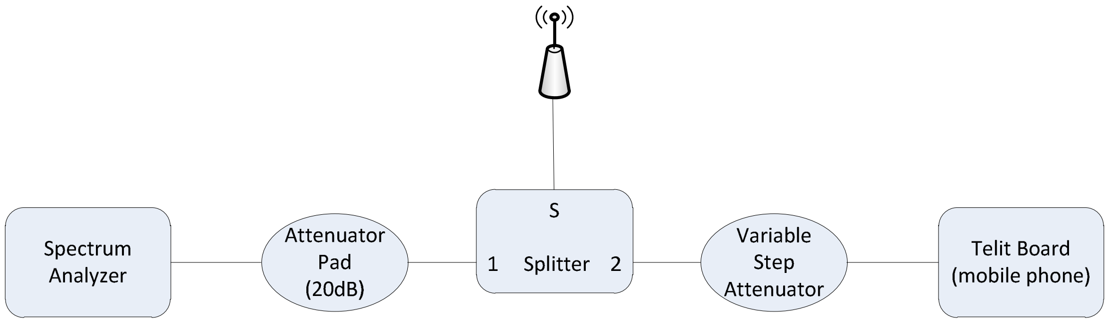


Figure 1: Measurement set up.

Table 1: List of Equipment

1.	Telit EVK2 GSM Developer's Evaluation Kit with manuals (mobile phone board)
2.	SIM card with a valid network subscription (Corr Wireless on AT&T/Cingular network)
3.	Larsen Special external cellular mobile antenna
4.	20 dB fixed bullet attenuator pad
5.	S.M. Electronics SA3550S manual step attenuator, 0-3000 MHz, 50dB, 1 dB step
6.	Mini-Circuits 15542 Splitter
7.	LMR-240 coaxial cables
8.	Anritsu Spectrum Master MS2721B spectrum analyzer
9.	Agilent ESG signal generator
10.	Personal computer running Windows 7 with PuTTY terminal emulator
11.	USB to DB9 (RS232) serial cable (PC to Telit EVK2 Interface)
12.	Landline telephone connected to PSTN

The Telit Board on the right of the figure could be commanded to send specific text messages as well as make voice calls. The antenna at the top of the figure received signals from a nearby base station. The splitter in the center sent signals to the Telit Board and a spectrum analyzer on the left. The variable attenuator allowed the Team to introduce excess attenuation so that the Telit Board could communicate normally with the base station when attenuation was set to be low, or, by increasing the attenuation, the Team mimicked weak or distant base station signals. The spectrum analyzer measured the signals from the antenna and also from the Telit Board. The Telit Board signal was relatively strong because it was connected through cables rather than over the air. The 20dB attenuator pad assured that the Telit Board signal was within the input limits of the spectrum analyzer.

The GSM SIM card installed in the Telit board carried the brand of Corr Wireless, a cellular reseller. Test calls and use of the FCC's Spectrum Dashboard website[29] were used to verify that spectrum in the range of 824 – 835 MHz and 845 – 846.5 MHz were used for the reverse link (phone to base station) and 869 – 880 MHz and 890 – 891.5 MHz were used for the forward link, licensed to AT&T/Cingular wireless. Testing determined that the local cell site control channel uplink was centered at 824.2 MHz. Further testing showed that the same frequency channel was used for all messages and all voice calls.

[29] "Spectrum Dashboard - Reboot.FCC.gov." [Online]. Available: http://reboot.fcc.gov/reform/systems/spectrum-dashboard. [Accessed: 29-Oct-2011].

The CU Team created test messages of 1, 60, and 160 characters. The 160 character message is the longest message that can be sent in any single SMS message. Each message was sent and observed using the spectrum analyzer. The spectrum analyzer, set at 824 MHz center frequency with resolution bandwidth of 1 MHz in zero-span mode, showed the channel activity over time. The uplink channel activity included messages from the Telit Board to the base station. Figure 2 below shows the spectrum analyzer output after a typical 160 character SMS message was sent.

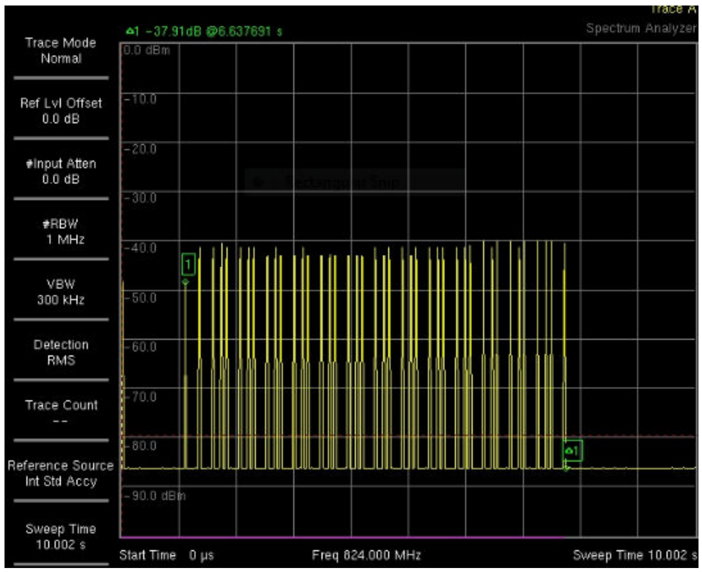
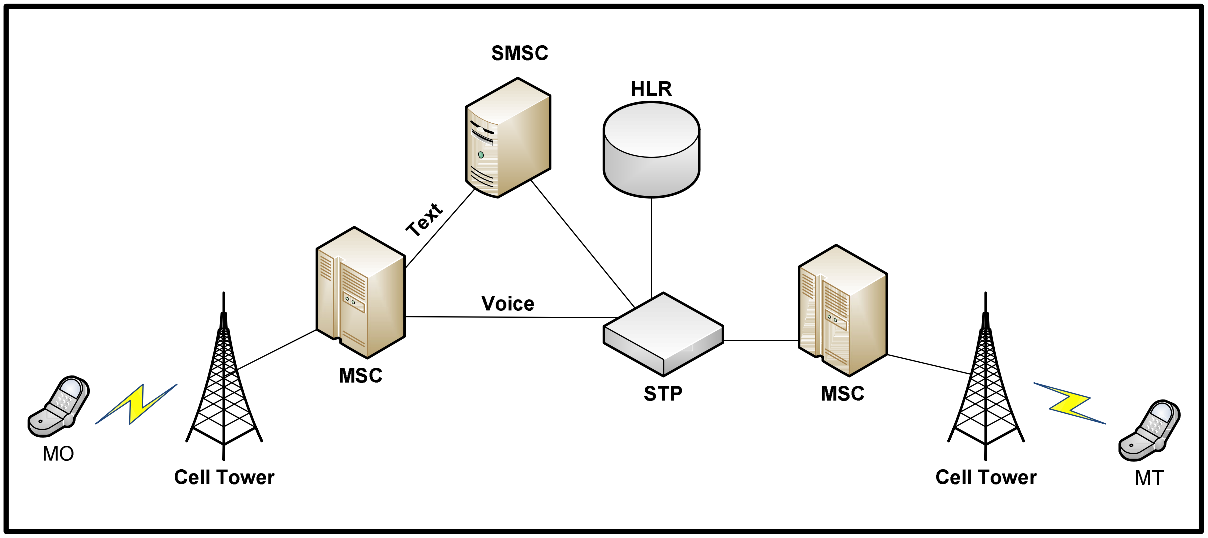


Figure 2: Typical observation of a text message being sent.

The various spikes represent different aspects of the GSM protocol; from the reverse access channel (RACH) message, labeled "1" to the final disconnect message, labeled "Δ1". What is important in the CU Team's measurements is the time from the first to the last spike. For instance, the time to send the SMS message in Figure 3 was 6.64 seconds. All reported results were based on at least 30 such measurements.



Source: (SMS Tutorial, n.d).

Figure 3: Basic Network Architecture for Voice and SMS Deployment

The SMS protocol includes an acknowledgement that the message was received by the mobile operator's SMS center. Thus, the reported measured times include the time to deliver the message through the receiving operators network to its SMS center.[30] As shown in the above figure, the time to reach the SMS center includes the time to be received by the cell tower and forwarded through the mobile switching center. Not included are a) the processing time between when the user presses send and when the message begins to be sent, nor b) the time to deliver the message from the SMS center to the final destination. In a mobile-to-mobile message, there would be a similar delay to send the message to the final user. However, in a 911 context, the message would be sent over wired links from the SMS center to the PSAP. The time for this was not observed because texting to 911 was not available.

In the case of voice calls, the spectrum analyzer provided a clear starting point when the call was initiated by the Telit board. However, a mobile phone sends "spikes" during call set up, ringing, and conversation. So, there was no clear delineation between these periods in the spectrum analyzer trace. To measure the duration of call setup the Telit Board was commanded to call a landline phone. When the landline began ringing, that point in time was noted in the spectrum analyzer trace, and the set up time was measured from the "first spike" to the "ring time". This measurement was less precise because it included human reaction times to mark the ring time. The error was estimated to be 0.1 seconds or less.

To set the variable attenuation, the attenuation was increased in one decibel (dB) increments until the Telit Board, in idle mode, indicated that it could no longer communicate with the base station. This cutoff attenuation level was found to be consistent over time. The lowest signal level at which the board could establish a connection was -109dBm. From this

[30] GSM Technical Specification, Digital cellular telecommunication system (Phase 2+); Point-to-point (PP) Short Message Service (SMS) support on mobile radio interface (GSM 04-11), ETSI TS/SMG-030411QR, March 1996.

operating point, the Team reduced the attenuation by 12 dB to simulate a good channel; or left the signal at -109dbm to represent a phone at the edge of coverage; or increased attenuation to guarantee that making a connections was not possible.

Through these methods, the CU Team found the following:

1. Reliability

The CU Team sent five hundred SMS messages when the signal level was at or exceeded the level of -109dBm. All of these messages were received for a measured reliability of 100%.

The team then compared its findings with other studies. The European Telecommunications Standards Institute (ETSI)[31] quotes approximately 98% reliability for SMS messages sent to a fixed network, but says 38% are not delivered on the first attempt for mobile-terminated messages, mostly due to unavailability of the receiver. A report from Finland estimates reliability exceeds 99%[32]. In Hong Kong users are advised that messages are not always reliable, and that they should resend their message or seek other means of assistance if an SMS acknowledgement is not received within five minutes[33]. A study of using GSM SMS for data collection found that the accuracy of data transmission via SMS was 100%. It showed a retransmission rate of 2.73% and data loss rate of 0.66%.[34]

2. Time to Dial 911(Make a Mobile Phone Call) versus Time to Compose and Send a Text Message.

With a strong signal, the CU Team's tests found that most of the time, a 60 character text message took 4.1 seconds to travel from the sending mobile phone to the SMS center, but occasionally (less than 10% of the time) it would take more than 5 seconds.

With a weak signal, when the caller is stationary, most of the calls took 4.8 seconds to send a 60 character message, but occasionally (less than 10 %) it took more than 7.8 seconds. The reason for this extended time was the time required for the "retry" attempts automatically generated by the system to establish a connection, and retries of individual packets within the connection.

Experience in Luxembourg showed that the time between sending and receiving an SMS message was less than five seconds[35]. An ETSI report states that mobile-to-mobile send times

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[31] European Telecommunications Standards Institute (ETSI) Special Committee Emergency Communications (EMTEL), "Analysis of the Short Message Service (SMS) and Cell Broadcast Service (CBS) for Emergency Messaging applications; Emergency Messaging; SMS and CBS," ETSI TR 102 444 V1.1.1, Feb. 2006. p. 11.

[32] *See* Ficora, *supra* note 14, p. 5.

[33] *See* Hong Kong Police Force, *supra* note 16.

[34] Chwan-Lu Tseng, Joe-Air Jiang, Ren-Guey Lee, Fu-Ming Lu, Cheng-Shiou Ouyang, Yih-Shaing Chen, Chih-Hsiang Chang, "Feasibility study on application of GSM–SMS technology to field data acquisition", *Computers and Electronics in Agriculture*, Volume 53, Issue 1, August 2006, Pages 45-59.

[35] *See* Bruck, *supra* note 19, p. 16.

should be six to eight seconds[36]. A report from Finland estimates the average delay for an SMS message is two seconds[37]. Theoretical calculations show that in a GSM network a 60 character message will take 3.2 seconds on average.[38] An extended study of SMS found an average of 3.2 seconds for the message to reach the SMS center. [39]

Message composition can be quick due to texting skill among some groups, better keyboard-like interfaces on some phones, and the ability to pre-store messages. The fastest rate of entering text (without any auto-complete functionality) is on the order of four characters per second.[40] However, for most users, various assists are helpful. Many smart phones have a small but familiar keyboard. Typing assistance that automatically completes words also helps. In Hong Kong, users are advised that they can store a message in their phone for faster and more accurate sending, particularly if they suffer from a chronic medical condition[41].

Smartphone applications exist to support this function. For the Apple iPhone *Advanced-911* sends texts, address, and GPS location to participating PSAPs. If a participating center is not available it assists in sending a message to a friend who can call 911.[42] For Android phones, the *Emergency QuickDial Widget* sends SMS alerts with helpful information like blood type, allergies, and person to contact.[43] *Emergency Button* sends a distress signal with GPS coordinates when pressed.[44]

3. Impact of Caller Movement

The strength of received signals in mobile environments varies greatly when the user moves. Even small movements on the order of 10 cm can have dramatic impact. The figure below

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[36] *See* ETSI, *supra* note 31, p. 11.

[37] Working Group For Emergency Communications, "Implementation of an SMS-Based Emergency Service in Finland," FICORA, Helsinki, Finland, Jul. 2005. p. 5.

[38] Collesei, S., di Tria, P.; Morena, G., "Short message service based applications in the GSM network," *Proc. of 5th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, 1994., vol.3, pp.939-943

[39] Chwan-Lu Tseng, Joe-Air Jiang, Ren-Guey Lee, Fu-Ming Lu, Cheng-Shiou Ouyang, Yih-Shaing Chen, Chih-Hsiang Chang, "Feasibility study on application of GSM–SMS technology to field data acquisition", *Computers and Electronics in Agriculture*, Volume 53, Issue 1, August 2006, Pages 45-59.

[40] There are several reports of texting 160 character messages in less than 40 seconds. http://en.wikipedia.org/wiki/Text_messaging

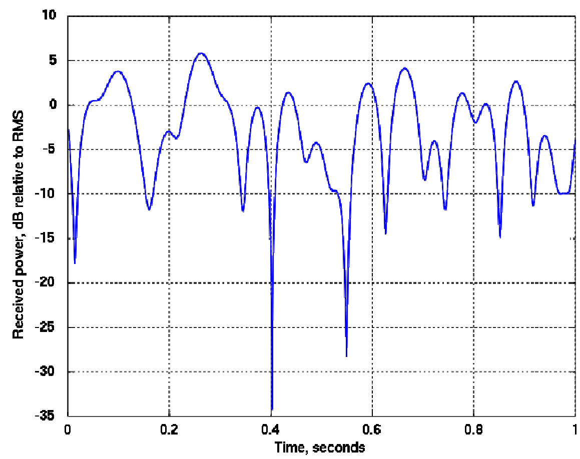
[41] Hong Kong Police Force, "992 Emergency SMS User Guide." Hong Kong Police Force, n.d. p. 3.

[42] Advanced 911 iTunes Preview: http://itunes.apple.com/us/app/advanced-911/id455783722?mt=8

[43] Android Market. Emergency QuickDial Widget: https://market.android.com/details?id=com.aportela.emergency

[44] Android Market. Emergency Button: https://market.android.com/details?id=com.emergency.button

shows how the signal varies over more than 20 dB (a factor of 100) many times every second for an 1800 MHz cellular user moving at 4 mph (1.7 meters per second).



en.wikipedia.org/wiki/Rayleigh_fading

Figure 4: Simulated signal variation over time.

The effect of movement and the resulting variability on the time to deliver a text message was measured in the lab for a pedestrian user. To simulate a walking caller, the team moved an antenna back and forth over a 4 meter straight line and sent a series of 60 character messages. The test started at a low signal with strength of -109 dBm. The majority of messages were sent in less than 5.1 seconds and occasionally (less than 10% of the time) were sent in more than 6.4 seconds. Note that the performance is similar to the previous weak signal level but with fewer long times. Though the channel has frequent fades to weaker levels, it is at a high level most of the time.

4. Weak Signal Environments:

With a fixed antenna (caller not moving), making a connection was possible whenever the received signal level was at or above -109 dBm. A connection was not possible when the signal level was below this level. This was true for both voice and text calls. For signal levels at the edge of coverage (-109dBm signal level), the time to send a typical message was 4.8 seconds but occasionally took more than 8 seconds. However, a one decibel increase in attenuation was enough to prevent communication.

As noted in the Section 3, movement by the caller causes highly variable signal level even when the phone only moves a few inches. At the edge of coverage small movements will cause the signal to swing in and out of coverage over short periods of time. At this edge of coverage both call and text attempts were observed to fail on some attempts and to be successful on other attempts. Though not fully explored at this time, the Team's anecdotal observations suggest that the texts are successful more often that voice. We were able to turn the attenuation to a high level where calls over several attempts never were successful while in the same situation several texts could be sent.

5. Impact of Message Length

We measured the time to send messages of 1, 60, and 160 characters. The results are in the table below. We note that the time to send the longest message is less than twice as long despite being 160 times longer. This is because, as noted above, the GSM protocol has connect and disconnect overhead that is present even for empty messages.

Table 2: Time to send a message as a function of message length.

Message size	Average delay time in seconds	Standard deviation in seconds
1 char	3.28	0.29
60 char	4.06	0.38
160 char	5.59	0.38

6. Confirmation of Test Message Delivery

Almost all international implementations of SMS to PSAP services include a step where the dispatcher initially receiving the text message sends a confirmation, including Finland[45], Hong Kong[46], Luxembourg[47], and the U.K.[48]. In the U.K. users are instructed to continue seeking help until their text is acknowledged[49]. An ETSI report notes that while an automatic delivery confirmation from the receiving station is possible, many users mistakenly assume the "message sent" display means the message was received[50]. In GSM, the "message sent" display is only an indication that the message has reached the mobile operators SMS center.

7. Dropped Calls

To measure dropped calls, the CU team established a voice call and then increased the attenuation of the signal to simulate a decrease in signal strength – much like a voice call on the edge of coverage. The call lasted 3 minutes unless it was dropped. Only 10% of the calls were dropped by the network.

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[45] Working Group For Emergency Communications, "Implementation of an SMS-Based Emergency Service in Finland," FICORA, Helsinki, Finland, Jul. 2005. p. 4, 9.

[46] Hong Kong Police Force, "992 Emergency SMS User Guide." Hong Kong Police Force, n.d. p. 2.

[47] C. Bruck, "112-SMS in Luxembourg." Administration des services de secours, n.d., p. 16.

[48] emergencySMS trial, "SMS to the emergency services | EmergencySMS," *emergencySMS*, 2009. [Online]. Available: http://www.emergencysms.org.uk/. [Accessed: 23-Aug-2011].

[49] J. Medland, "UK - Emergency SMS Trial." British Telecommunications plc, n.d.

[50] European Telecommunications Standards Institute (ETSI) Special Committee Emergency Communications (EMTEL), "Analysis of the Short Message Service (SMS) and Cell Broadcast Service (CBS) for Emergency Messaging applications; Emergency Messaging; SMS and CBS," ETSI TR 102 444 V1.1.1, Feb. 2006. p. 11.

The CU team used the standard measure of the quality of the received signal[51] (denoted RxQual) that the phone self-reported at the end of each call. The RxQual is a measure of the Bit Error Rate (BER) on the channel; the lower the errors, the better the signal. Thus, a gross BER greater than 12.8% equals an RxQual of 7, a gross BER between 6.4% and 12.8% equals an RxQual of 6, and a BER between 0.8% and 1.6% equals an RxQual of 4. The literature[52] states that RxQual values below 4 are desirable because at that level, almost all bit errors can be corrected by a channel decoder. In our study of calls at a weak signal level, the phone reported RxQual values of 6 and 7. These are not an acceptable form of communication by (mobile) phone.[53]

8. Continuity/Consistent Contact with 911 Call Takers

Technology exists to deliver successive messages to the same PSAP operator. Such technology was reported as implemented in text to 911 systems in Finland, Norway, and Canada [54], [55], [56].

9. Congestion in Public Telephone Networks

The performance of PSAP communication should be considered in the light of the general environment within which it is operating. For instance, delays may be higher when traffic on the public network is high and communication channels are congested. Similarly, a PSAP operator may be more likely to be busy and unable to answer a call when there is a surge of 911 calls. Depending on the level of both the public network traffic and PSAP traffic we define four regimes shown in the diagram below.

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[51] ASCOM – TEMS Investigation, 2009, " FER, RxQual, and DTX DL Rate Measurements", pp 1-14, accessed October 30, 2011, http://www.cn.ascom.com/cn/measurements-in-investigation-2.pdf

[52] Werner M, Kamps K., Tuisel U., Beerends J., and Vary P., "Parameter based speech quality measure for GSM", *International Symposium on Persona1,lndoor and Mobile Radio Communication Proceedings,* 14th annual IEEE 2003,
http://www.ind.rwth-aachen.de/fileadmin/publications/werner03.pdf

[53]ASCOM – TEMS Investigation, 2009, " FER, RxQual, and DTX DL Rate Measurements", pp 1-14, accessed October 30, 2011,
http://www.cn.ascom.com/cn/measurements-in-investigation-2.pdf

[54] Working Group For Emergency Communications, "Implementation of an SMS-Based Emergency Service in Finland," FICORA, Helsinki, Finland, Jul. 2005. p. 9.

[55] The National Center on Emergency Communication in Health (Norway), "SMS in Emergency Communication," National Center on Emergency Communication in Health (Norway), Bergen, Norway, 978-82-8210-017-5, Nov. 2009. p. 10.

[56] Canadian Radio-television and Telecommunications Commission, Interconnection Steering Committee (CISC), "Text Messaging to 9-1-1 (T9-1-1) Service," ESRE0051, Jan. 2010. p. 48.

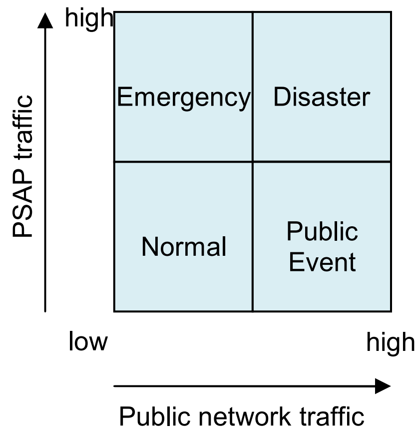

Figure 4: Congestion Call Scenarios.

The vertical axis indicates traffic to the 911 system, while the horizontal axis indicates traffic on the general public telephone network. Each moves from "normal" traffic volumes to "high" volumes of calls and defines different operation regimes.

- *Normal* situations are when neither the PSAP nor public network is congested. This is the case most of the time when a single or small number of callers attempt to report an isolated event to a PSAP. Examples include a home medical emergency or a burglary.
- E*mergency* situations, including multi-vehicle highway accidents, the sound of gunshots or other events, trigger many people to call 911. In such cases, the nearest PSAP experiences a surge of calls that must be answered to: (1) discern any additional useful information about the event, and (2) capture other calls unrelated to the first event, such as a person having a heart attack. During these e*mergency* situations, traffic on the general public telephone network may remain relatively stable or unaffected.
- *Public events* occur, such as a major political convention, football game, or news story, that causes heavy call traffic on the general public network, but no significant call loads to 911.
- *Disasters* occur, such as earthquakes or bombings, and nearly everyone involved immediately calls loved ones to find them, check on their safety, and sometimes, to call (911) for help. At the same time, persons from outside the affected area call into the affected area to check on family and friends. Delays under these conditions are high since calls on both the general public and 911 networks are clogged and make the network nearly impossible to use. Additionally, the communications infrastructure may be damaged, reducing the number of circuits or communication's lines available. Since the goal in a disaster is to manage the (network) congestion so that 911 calls can be carried by the public network, minimize the use of public network and PSAP resources, and enable the PSAP to effectively triage incoming calls and manage public safety resources.

In this section we address the case when the traffic on the public network is high (Public Event or Disaster). A significant bottleneck in the mobile network is the radio channel. One advantage of a SMS is that it uses fewer network resources. First, as measured above, the

SMS message occupies the channel for about four seconds compared to a voice call which is typically 110 seconds.[57] Thus, each text uses many times less channel time than a voice call. In GSM there is a further advantage that each traffic channel can simultaneously support 8 SMS connections.[58] However, a typical text to 911 session requires 6 SMS to be sent in each direction (12 SMS total).[59] Thus, a text to 911 session is equivalent to a 6 second voice call.[60] The net result is that the text 911 session uses about 18 times fewer channel resources than a voice 911 session.

In text to 911 when a message refers to an already reported event, it is easy to respond to the caller to end the session, e.g. “We are aware of the building fire on 1650 Main Street. Send again if you need to report a further emergency.” In this situation the number of texts sent would only be two (one to the PSAP, and the PSAP response). Two instead of 12 messages sent would use even fewer channel resources (equivalent to a one second voice call). A voice 911 call taker can provide a similarly terse response but compared to texting the voice call would take a similar factor of 18 more resources for the call to be setup, the caller to explain the emergency, and then for the call taker to respond that the emergency is being addressed. The fact that text users and call takers compose and read messages offline and only use communication for the moment that the message needs to be sent saves valuable network resources during network congestion.

10. Congested Call Loads at the PSAP

In cases when the load on the PSAP is high (e.g. an Emergency or Disaster in Figure 4), text to 911 can have several operational advantages. The messages are already in a form that can be read by a machine to filter and even generate an automatic response. Natural language processing techniques for reading and filtering text messages have been developed for Twitter which generates messages similar to texts.[61] Such techniques can automatically extract situational information before being read by a human. Such situational awareness can incorporate other sources of information (e.g. Twitter tweets) and could convey the extracted situation out to the public (e.g. by tweeting out that emergency responders are on the way to a fire).[62] They can cluster texts related to the same event and enable a single call taker to scan and respond to all as a group, to pull together separate pieces of information about the same

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[57] CTIA semi-annual wireless industry survey, 2011, http://files.ctia.org/pdf/CTIA_Survey_MY_2011_Graphics.pdf

[58] Using the so-called Stand-alone Dedicated Control Channel (SDCCH).

[59] John Snapp, personal communication, Dec. 1, 2011.

[60] (4 sec SMS channel/SMS)(12 SMS/session)(1 voice channel/8 SMS channel) = 6 sec voice channel/session.

[61] Verma, Sudha, Sarah Vieweg, Will Corvey, Leysia Palen, Jim Martin, Martha Palmer, Aaron Schram and Ken Anderson. Natural Language Processing to the Rescue? Extracting “Situational Awareness” Tweets During Mass Emergency. In the *Fifth International AAAI Conference on Weblogs and Social Media*, 17-21 July 2011, Barcelona, Spain.

[62] Palen, L., Anderson, K. M., Mark, G., Martin, J., Sicker, D., Palmer, M., and Grunwald, D. (2010). A vision for technology-mediated support for public participation and assistance in mass emergencies and disasters. In Proceedings of the 2010 ACM-BCS Visions of Computer Science Conference (Edinburgh, United Kingdom, April 14 – 16, 2010). ACM-BCS Visions of Computer Science. British Computer Society, Swinton, UK, 1-12.

event, and to pull out emergencies that are incorrectly assigned to the cluster. Even for disparate events it is possible for a single call taker to monitor several sessions simultaneously. Call centers routinely have a single operator monitor multiple chat sessions.[63] When a PSAP becomes overloaded it is easy to forward a text session to another PSAP where a new call taker can scan the texts exchanged so far and quickly pick up the thread. This change would be less disruptive then forwarding a caller to a new voice who needs to be told again the situation.

IV. CONCLUDING REMARKS/COMMENTS

The University of Colorado's ITP appreciates the opportunity to comment on the NG911 NPRM to: 1) enable the public to send emergency communications to 911 Public Safety Answering Points (PSAPs) via text, photos, videos, and data, and 2) enhance the information available to PSAPs and first responders for assessing and responding to emergencies, while also ensuring reliable voice-based 911 service.

Respectfully submitted by,

Timothy X. Brown, Director

Sharon K. Black, Project Director/Adjunct Professor

University of Colorado, ITP, Boulder, CO, 80309-0530
(303) 492-1630

[63] Call center software advertises that experienced operators can handle up to 6 simultaneous sessions. http://www.whoson.com/call-center-live-chat.aspx